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Geostationary Operational Environmental Satellite (GOES-N Report)
Executive Summary

(U.S.) National Aeronautics and Space Administration, Greenbelt, MD

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GEOSTATIONARY OPERATIONAL ENVIRONMENTAL SATELLITE

GOES-N

REPORT

EXECUTIVE SUMMARY

Prepared by

Advanced Missions Analysis Office

Goddard Space Flight Center

December, 1991

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Harry E. Montgomery, Study Project Manager
Robert F. Adler, Study Project Scientist

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TABLE OF CONTENTS

FOREWORD

The Advanced Missions Analysis Office (AMAO) of the Goddard Space Flight Center (GSFC) has completed a study of the Geostationary Operational Environmental Satellites (GOES-N) series. Evaluated were the feasibility, risks, schedules, and associated costs of advanced space and ground system concepts responsive to National Oceanic and Atmospheric Administration (NOAA) requirements. The study is the first step in a multi-phased procurement effort that is expected to result in launch ready hardware in the post 2000 time frame.

The study was initiated in response to a NOAA request to the National Aeronautics and Space Administration (NASA) for a Phase-A feasibility study in November 1988. Preliminary planning for the study at both GSFC and NOAA began in early 1989 with a NOAA sponsored GOES-N Requirements Working Group meeting. A formal GOES-N requirements document was issued by NOAA in May 1989. Funding to proceed with the study was received at GSFC in October 1989.

This report represents the latest activity of GSFC in translating meteorological requirements of NOAA into viable space systems in geosynchronous earth orbits (GEO). GOES-N represents application of the latest spacecraft, sensor, and instrument technologies to enhance NOAA meteorological capabilities via remote and *in-situ* sensing from GEO.

The GOES-N series, if successfully developed, could become another significant step in NOAA weather forecasting space systems, meeting increasingly complex emerging national needs for that agency's services.

SUMMARY OF CONTENTS OF THE GOES-N STUDY REPORT

The GOES-N study consisted of five distinct tasks including:

- Determining replication costs of GOES I-M and GOES-7 in the GOES-N time frame,
- Defining and evaluating modifications to GOES I-M to improve efficiency or reduce costs,
- Defining evolutionary changes to the GOES I-M design to satisfy National Weather Service (NWS) 1983 and NOAA 1989 requirements.

The GOES-N Study Report refers to the results of the GOES I-M replication cost study. A report of this task was completed and transmitted to NOAA in September 1989. This report is currently being updated to reflect the latest developments in the GOES I-M program. The GOES-7 replication cost study report is being prepared as a separate document.

The categorization and disposition of NOAA requirements is reported in Volume 1 Section 4. Results of the GOES I-M efficiency/cost improvement modifications study are described in Section 7.1. The system concept Options I, II, and III that generally represent the results of the Task 2, 3A, and 3B studies are summarized in Section 7.2. Another result of the GOES-N study - the determination of which NWS 1983 and NOAA 1989 requirements can be met with the three options is contained in Volume 1 Section 7.

Conclusions and Recommendations are covered in Volume 1 Section 8. Imager, sounder, control system, Space Environment Monitor, Search and Rescue, Weather Facsimile, Data Collection System, and Products/Process/Communications recommendations have been extracted from Sections 9, 10, and 11. Section 8 also contains conclusions pertaining to programmatic operational satellite issues (prerequisite development strategies, the direct procurement of instruments by the government, protoflight missions, etc.).

Sections 9, 10, and 11 address instrument, control system, Image/Navigation/Registration, and other system design considerations and surveys. These sections are supported by the appendices in Volume 2.

ACRONYMS, ABBREVIATIONS, UNITS OF MEASURE, SYMBOLS

ACRONYMS & ABBREVIATIONS

ACE	Attitude Control Electronics
ACS	Attitude Control System
AIRS	Atmospheric Infrared Sounder
AMAO	Advanced Missions Analysis Office
ATS	Applications Technology Satellite
AWIPS	Advanced Weather Interactive Processing System
CDA	Command and Data Acquisition
DCP	Data Collection Platform
DCPR	DCP Response
DCS	Data Collection Systems
DOC	Department of Commerce
DOMSAT	Domestic Communications Satellite
DUS	Data Utilization Station
EIRP	Effective Isotropic Radiated Power
EOS	Earth Observing System
EPS	Energetic Particle Sensor
ES	Executive Summary
EUV	Extreme Ultraviolet Instrument
GEO	Geosynchronous Earth Orbit
GFRP	Graphite Fiber Reinforced Plastic
GOES	Geostationary Operational Environmental Satellite
GPS	Global Positioning Satellite
GSFC	Goddard Space Flight Center
GTO	Geosynchronous Transfer Orbit
GVAR	GOES Variable data format
GVHRR	Geosynchronous Very High Resolution Radiometer
Hα	Hydrogen–alpha
HαI	Hydrogen – Alpha Imager
HAC	Huges Aircraft Company
HIS	High–resolution Interferometer Sounder
HSRS	High Spectral Resolution Sounder
IFOV	Instantaneous Field of View
IGFOV	Instantaneous Geometric Field of View
INR	Image Navigation and Registration
INSAT	Indian Satellite
IR	Infrared
IRU	Inertial Reference Unit
ITT	International Telephone & Telegraph Company
IUE	International Ultraviolet Explorer
LMS	Lightning Mapper Sensor
LPS	Low energy Plasma Sensor
MDL	Multiuse Data Link
NASA	National Aeronautics Space Administration
NEΔN or NEDN	Noise Equivalent Delta Radiance
NEΔT or NEDT	Noise Equivalent Delta Temperature
NESDIS	National Environmental Satellite & Data Information Service
NOAA	National Oceanic and Atmospheric Administration
NWS	National Weather Service
OMB	Office of Management and Budget
PPC	Products, Process, and Communications
PSK	Phase Shift Key
QPSK	Quadraphase Shift Key
RAO	Resources Analysis Office

RC1, RC2, ...	NOAA Core Requirements
RE1, RE2, ...	NOAA Enhanced Requirements
RFP	Request for Proposal
RO1, RO2, ...	NOAA Option Requirements
ROM	Rough Order of Magnitude
R&D	Research and Development
S&R	Search and Rescue
SBRC	Santa Barbara Research Center
SDL	Sounder Data Link
SEM	Space Environment Monitor
SMM	Solar Maximum Mission
S/N or SNR	Signal to noise ratio
SOCC	Satellite Operations Control Center
SS/L	Space Systems/Loral
SSPA	Solid State Power Amplifier
SVM	Solar Vector Magnetograph
SXI	Solar X-Ray Imager
TEC	Total Electron Content
UHF	Ultra High Frequency
USAF	United States Air Force
VAS	VISSR Atmospheric Sounder
VHF	Very High Frequency
VIS	Visible
VISSR	Visible Infrared Spin Scan Radiometer
WEFAX	Weather Facsimile
XRS	X-Ray Sensor

UNITS OF MEASURE

μm	micrometer
μrad or μr	microradian
A	amperes
arcmin	arcminute (minutes of arc)
arcsec	arcseconds (seconds of arc)
bps	bits per second
^{0}C	degree centigrade
^{0}	degrees (temperature and angles)
Db	decibels
eV	electron volts
ft	feet
Hz	hertz
in	inch
K	degrees kelvin
kbps	kilobit per second
keV	thousand electron volts
Khz	kilohertz
kg	kilogram
km	kilometer
lb	pounds
m	meter
mbar	millibar
Mbps	million bits per second
MeV	million electron volts
MeV/n	million electron volts per nucleon
Mhz	megahertz
min	minute
mrad	milliradian

ms	millisecond
mT	millitesla
mW	milliwatt
nm	nanometers
nT	nanotesla
rad	radian
RH	relative humidity
s	second
V	volt
W	watt
Z	atomic number

SYMBOLS

σ	standard deviation
υ	wave number
f#	f–number
Δ	delta

EXECUTIVE SUMMARY

GOES-N STUDY REPORT

OBJECTIVES

The GSFC AMAO has completed a NOAA-requested GOES-N study with the following objectives:

- Generate advanced space and ground system concepts to meet NOAA requirements in the post GOES I-M time frame.
- Evaluate the feasibility, risks, schedules, and costs of these concepts.
- Determine replication costs of the GOES I-M series in the same time period.
- Determine replication costs of the GOES-7 system in the same time frame. This task was requested of the Department of Commerce (DOC) by the Office of Management and Budget (OMB). The study was funded in December 1990, approximately one year after the GOES-N study formally began.

BACKGROUND

Even as the GOES I-M series of meteorological satellites was in the process of development, NOAA had already begun its internal deliberations for a post GOES I-M geosynchronous earth orbiting follow-on called GOES-N. NOAA considerations for this advanced mission included:

- The GOES I-M program status,
- Expected advances in instrument and sensor capabilities,
- Newly emerging NOAA science requirements,
- The projected NWS modernization program currently underway,
- New spacecraft developments including the NASA geoplatform system.

As a result of these and other related factors, initial correspondence between NOAA and NASA pertaining to conducting a GOES-N Phase-A study was exchanged beginning in 1988.

A GOES-N Phase-A study was subsequently authorized within NASA in January 1989, and GSFC's AMAO, and the Resources Analysis Office (RAO) began developing a study plan that included an approach and resource requirements.

In parallel with planning for the GOES-N study, NOAA had established a GOES-N Requirements Working Group. Its first meeting, in January 1989, resulted in an initial list of requirements which was distributed for review in April 1989 at the GOES I-M Conference. A final list, delivered to GSFC in May 1989, was used as the basis for system requirements in the GOES-N Phase-A Study Plan.

When the study plan was presented to NOAA for review in April–May 1989, it was learned that the agency's budget limit for the study was $1.56M. The RAO estimate for the study was $4 – $6M; the AMAO estimate was $3.0 – $4.3M. This required an adjustment of the depth and scope of the study as originally defined. By virtue of this, the name of the study was officially changed by verbal order of the Director, GSFC, to GOES–N Study. Funding for the study was received by GSFC in October 1989. A final presentation of study results was held 31 October – 1 November 1990.

STUDY APPROACH

NOAA study guidelines resulted in the definition of five distinct tasks to meet the objectives:

1. Determine the cost of replicating the GOES I–M series in the GOES–N time frame.
2. Define candidate evolutionary modifications to the GOES I–M system that would result in efficiency improvements and/or cost reductions. Evaluate these with regard to cost, schedule, and risk impacts as well as feasibility.

3A. Determine evolutionary changes to the GOES I–M design that will satisfy NWS 1983 requirements not included in GOES I–M specifications. Evaluate these with regard to cost, schedule, and risk impacts as well as feasibility.

3B. Task 3A "NWS 1983 requirements" replaced with "NOAA 1989 requirements."

4. Determine the cost of replicating the currently operational GOES–7 in the GOES–N time frame.

TASK 1

A modeled cost estimate for GOES I–M was initially developed after which replication costs in the GOES–N time frame were determined. Metsat Project and RAO hypotheses were used in generating the modeled cost estimate and compared with actual GOES I–M expenditures. Major ground rules used in deriving the replication cost figures were: the GOES I–M contractor would build the new series; GOES–N would be an exact replica of GOES I–M; GOES–I spacecraft and instrument weights were used for costing purposes; and the fabrication time period for the initial mission replication was estimated to be four years.

TASKS 2, 3A, and 3B

Requirements were initially classified as Core, Optional, or Enhanced (Appendices 1 through 6) depending on the importance of the measurement parameters to NOAA. For each NOAA requirement, one or more specific studies were defined as being necessary to the Phase–A study (Appendix 7). Some studies were applicable to more than one requirement. Resources required to perform each study were determined and translated into contractor or civil service manpower and associated costs. The studies were ranked in priority order in cooperation with NOAA after having been subjected to a complex analysis procedure that involved designation of the study as a Task 2 "improvement modification" or a Task 3A/3B system design change. For each resulting modification or change, its value in meeting NOAA requirements was also estimated. The prioritized list of studies was achieved after a succession of "tall poles," study payoffs, and scientific and study benefits had been calculated.

The priority rankings compared with resource constraints were used as a basis for selecting the studies which would be accomplished (Appendix 8) within the scope of the GOES-N study. The remaining studies were relegated to a "recommended before Phase-B begins" category (Appendix 9). The depth of the effort was further defined in terms of detailed analyses for the imagers and sounders and less labor intensive "surveys" for the Data Collection System (DCS), weather facsimile (WEFAX), Search and Rescue (S&R), Space Environment Monitor (SEM), and related ground systems.

As the analyses and "surveys" proceeded, the focus of the effort evolved into the definition of specific candidate concepts that could potentially satisfy NOAA requirements and study objectives. It soon became apparent that three system options would need to be developed to address the Core plus the more difficult to achieve Optional and Enhanced NOAA requirements and be responsive to Tasks 2, 3A, and 3B respectively. Table 1 is a matrix of spacecraft, instrument, and launch vehicle concepts as functions of the three options.

Cost estimates (Volume 3) were prepared for each of these three options by the RAO in accordance with certain basic assumptions and on the basis of "business as usual" and a "preferred strategy". The first set of cost estimates is patterned after the GOES I-M method of developing an operational satellite system. The "preferred strategy" assumes a prerequisite continuing research and development (R&D) program (implies research missions, protoflights).

TASK 4

The GOES-7 replication (in the GOES-N time frame) cost estimate was prepared in conjunction with the RAO on the same basis as Task 1, the GOES I-M replication cost estimate.

STUDY RESULTS

A significant number of NOAA requirements (Appendices 1 through 6) were satisfied by the three system options. Approximately 20 requirements (Table 2, and Appendix 10) were not deemed achievable for reasons primarily involving exceeding the state-of-the-art anticipated for the GOES-N time frame. Requirements are further discussed in RECOMMENDATIONS AND CONCLUSIONS section of this summary. The study results also indicate that some modifications, listed below, would result in a GOES I-M derived spacecraft and instrument complements with significant performance and requirement improvements. The cost analyses (Volume 3) project a much lower overall system cost and higher reliability if a "preferred strategy" is used for GOES-N. This strategy assumes that R&D efforts accompany or precede Phase-C/D.

MODIFICATIONS TO GOES I-M (TASK 2)

Six specific Task 2 modifications to the GOES I-M series, expected to increase efficiency or reduce costs, were identified and described. They are:

1. Techniques for decreasing sounder alignment times.
2. Remote adjustment mechanisms to perform final alignment of imager/sounder focal planes

during instrument thermal vacuum tests to minimize mechanical stress.

3. Long life flex pivots for the imager east–west scanner to minimize the current ball bearing travel distance which is about 2,000 times greater than that of the north–south scanner bearing assembly on the GOES–7 Visible Infrared Spin Scan Radiometer (VISSR) Atmospheric Sounder (VAS).
4. Positive temperature control of the imager aft optics to improve channel–to–channel co-registration performance.
5. Improve the GOES–I imager by utilizing a modest growth weight allowance with no significant change in spacecraft interface requirements.
6. Improve the imager/sounder noise equivalent delta temperature (NEΔT) by decreasing the control temperature (to 92K) using a lower emissivity reflector on the Astromast boom.

TABLE 1: GOES–N PAYLOAD/SPACECRAFT/LAUNCH VEHICLE MATRIX

DESCRIPTION	BASELINE ATLAS II	OPTION I ATLAS II	OPTION II ATLAS IIA	OPTION III ATLAS IIAS
Spacecraft (I–M bus)	X	X	—	—
Spacecraft (other)	—	—	X	X
Imager	X	—	—	—
Imager (improved)	—	X	—	—
Imager (7 bands)	—	—	X	—
Imager (new)	—	—	—	X
Imager (additional)	—	—	—	X
Lightning mapper	—	—	X	X
Sounder	X	—	—	—
Sounder (improved)	—	X	—	—
Sounder (high spectral res., passive cooler)	—	—	X	—
Sounder (high spectral res., active cooler)	—	—	—	X
WEFAX	X	X	—	—
WEFAX (new)	—	—	X	X
Data Collection System	X	X	—	—
Data Collection System (new)	—	—	X	X
S&R	X	X	X	X
S&R (new)*	—	—	—	—
SEM:				
Energetic Particle Sensor (EPS)	X	—	—	—
EPS (improved)	—	X	X	X
Magnetometer	X	X	X	X
X–Ray Sensor	X	X	X	X
Solar X–Ray Imager (new)	X	X	X	X
Low Energy Plasma Sensor	---	X	X	X
Solar Magnetograph/H–Alpha	---	---	---	X
Total Electron Content	---		---	X

* S&R (NEW) HAS POSITION LOCATION CAPABILITY

TABLE 2: UNMET NOAA REQUIREMENTS VERSUS SPACECRAFT OPTIONS

GOES-I	OPTION I	OPTION II	OPTION III
	Essentially supports core requirements	**Essentially supports optional requirements**	**Essentially supports enhanced requirements**
		RO1: (1) Increased resolution unmet in 2 IR bands) (2) Add spectral bands: (low SNR in 13μm band)	Increased resolution unmet in 1 IR band. Diffraction limited to 4km in 10μm band. Low SNR in 13μm band
42μr, pixel-pixel (75)	RC3: 42μr, pixel-pixel (75)	RO3: 14μr, pixel-pixel (37)	(33)
28μr, chan-chan (60)	RC4: 14μr, chan-chan (50)	(40)	(30)
84μr, image-image (69)	RC5: 42μr, image-image (69)	RO5: 14μr, image-image (33)	(29)
Sensitivity performance (?)	RC7: sensitivity (? GOES-I)	RO7: sensitivity (? GOES-I)	Met in some channels
	RC8: cloud smear: new spec required	RC8: cloud smear: new spec required	RC8: cloud smear: new spec required
			RE13: cal. vis chan. (possibly)
			RE14: low light imager; modify lightning mapper; IFOV=10km
		RO18: 2km contemporaneous IR	
		RO20: single pixel sounding	
			RE21: spatial resolution <=4km (diffraction limited)
Sounding rate: $(3000km)^2$ <40 minute. (39.3 minute.)		RO22: sounding rate: $(3000km)^2$ <=30 minute. (major problem: NEΔT)	(major problem: NEΔT)
	RC25: sounder: (1) match centroids to 2%/4.5μr (10μr) (2) half-power IGFOV <1%/2.2μr (20μr)	(10) (20)	(10) (20)
	RC31: (1) pitch angle distributions - protons & electrons above 30keV not provided. (2) alpha particle measurements not provided below 800MeV/N		
		RO33: solar EUV spectrometer not provided	
	RC35: S&R: no location	(no location)	(no location, under study)
	RC36: DCS: (1) additional channel (GOES-I) (2) no location	(no location)	(no location)
	RC37: WEFAX: (1) 4 channels (GOES-I) (2) no eclipse operations		

Key: numbers are specified values or requirements; numbers in parentheses are expected performance

A modification of the imager using low thermal expansion coefficient structural materials would significantly improve pointing performance. Discussed in Volume 1 Sections 7.1.4 and 10.4.1.3.1, this change, although highly desirable, was considered more a design change than an evolutionary change and, consequently, was not included in the Task 2 list above. Low thermal coefficient structural material was, however, included in the Option III imager design.

OPTION I RESULTS

When the study team defined the three options presented in this report as strawman spacecraft systems, the concept underlying the Option I spacecraft was that of a minimal cost program based almost exclusively on the GOES I-M heritage. This implies that GOES-N would be virtually identical to GOES-M in all respects, with changes only where cost and efficiency improvements could be made. The assumption is, therefore, that GOES-M instruments will meet the core requirements, which in most cases are those currently specified for GOES-I. The Option I concept was broadened to allow instrument changes where the fundamental design approach is not changed and where the changes do not alter the spacecraft interface, i.e., power, weight, volume, footprint, telemetry, etc.

OPTION I

TASK:

- MODIFY GOES I-M BUS TO ACCOMMODATE EFFICIENCY IMPROVEMENTS AND/OR COST REDUCTIONS

RESULTS:

- FEASIBLE; LOW RISK; SCHEDULE IMPACT OF CHANGES MODEST; SOME NON-RECURRING COSTS
- SOME ADDITIONAL REQUIREMENTS MET BEYOND GOES I-M
- RECOMMENDED OVER TASK I BECAUSE OF POTENTIAL IMPROVEMENTS AND COST REDUCTIONS

SPACECRAFT:

- MODIFIED GOES I-M BUS: IMPROVED CONTROL SYSTEM/EARTH SENSOR

PAYLOADS:

IMAGER: IMPROVED NAV. & REG., SERVO, OPTICAL ENCODER
SOUNDER: IMPROVED CO-REGISTRATION
WEFAX: LIKE GOES I-M
DCS: LIKE GOES I-M
S&R: LIKE GOES I-M
SEM:
EPS: IMPROVED
MAGNETOMETER: LIKE GOES I-M
XRS: LIKE GOES I-M
SXI: PROPOSED FOR GOES M
LOW ENERGY PLASMA: NEW

OPTION II RESULTS

The Option II concept is progressively more improved, costly and complex than Option I but less so than Option III. Except for the imager, the constraint of utilizing modified GOES I–M designs is abandoned, but a theme of evolutionary improvements is maintained. The resulting Option II concept incorporates a different spacecraft bus modeled after the Hughes Aircraft Company (HAC) HS601, an existing and seasoned design. The proposed system essentially satisfies the 1989 NOAA requirements. The principal system enhancements recommended are:

1. Improved passive cooler operation for both imager and sounder
2. Improved Image, Navigation, and Registration performance
3. Increased sounding spectral resolution

The payload items that are different from Option I are the sounder, Lightning Mapper Sensor (LMS), WEFAX, and DCS. Imager changes were limited to those that did not require the GOES I–M design concept to be changed. The addition of the two channels (0.86 μm and 1.65 μm) specifically requested by NOAA can be implemented without impact to the cooler design. Modifying the imager to improve mirror pointing performance will be accomplished by swapping inductosyn mirror drives with optical encoder drives and limiting the encoder size to fit in the inductosyn space. This is a very productive change because of the greater inherent accuracy of the optical encoders. The GOES I–M imager electronics were slightly enlarged to accommodate circuitry for the additional spectral channels. Performance improvements gained by operating at a lower focal plane temperature were accomplished for this concept by completely eliminating the solar sail and by doing a half–yearly 180 degree yaw maneuver to minimize solar incursions on the passive cooler.

The Option II High Spectral Resolution Sounder (HSRS) is a passively cooled Michelson interferometer. Optics aperture size has been increased from 12 to 14 inches.

As with the imager, the sounder performance is improved by eliminating the solar sail using the semi–annual 180 degree yaw maneuver to keep the sun off the cooler. The baseline design approach for the Option II sounder is to send the digitized interferogram to the ground without in–orbit signal processing. Greater reliability is realized by ground processing, and the communication system can handle the required data rate without a significant downlink power increase. The LMS proposed for Option II is essentially the same instrument that had been scheduled for flight on the GOES I–M series.

WEFAX is changed from GOES I–M and Option I to add three additional channels, for a total of four. The new channels are a second analog WEFAX channel, a digital WEFAX channel operating at 19.2 kbps, and a 50 kbps data channel referred to as the NOAA port. The stated purpose of the 50 kbps channel is to broadcast DCS products from the Command and Data Acquisition (CDA) to DCS users and also to distribute some NOAA weather products. This channel will replace a leased Domestic Communications Satellite (DOMSAT) service, that will replace the dial–up service currently in use. An additional requirement is to have the WEFAX system operate during eclipse periods.

OPTION II

TASK:

- SYSTEM DESIGN CHANGES TO ESSENTIALLY SATISFY OPTIONAL NOAA REQUIREMENTS

RESULTS:

- FEASIBILITY: CONTINGENT UPON REQUIREMENT CHANGES & PRIOR DEVELOPMENT OF INSTRUMENTS AND SPACECRAFT COMPONENTS
- RISK: MODERATELY HIGH. SUITABLE FOR OPERATIONAL USE IF PRIOR DEVELOPMENT OCCURS
- SCHEDULE: VARIABLE DEPENDING ON DEVELOPMENT BEING SEPARATE OR INCORPORATED IN PHASE-B,C,D
- COST: HIGH NON-RECURRING, HIGHER RECURRING (COMPARED WITH OPTION I)
- TASK EVOLVED INTO SATISFYING MORE CORE AND OPTIONAL REQUIREMENTS THAN OPTION I

SPACECRAFT (DIFFERENT BUS):

- IRU SYSTEM (STAR SENSOR/GYROS) – 10 μr
- REACTION WHEELS
- ADDITIONAL BATTERIES
- IMPROVED SOLAR ARRAY

PAYLOADS:

IMAGER*:	6 IR & 2 VIS. BANDS, IMPROVED SERVO., INCHWORM, MULTI FOCAL PLANE, CO-REGISTRATION MAY BE PROBLEM
ADV. SOUNDER:	HIGH SPECTRAL RESOLUTION
LIGHTNING MAPPER:	LIKE GOES M PROPOSAL
WEFAX:	ADDITIONAL CHANNELS
DCS:	INCREASED CAPACITY – NO LOCATION CAPABILITY
S&R:	LIKE GOES I-M – NO LOCATION CAPABILITY
SEM:	

EPS:	LIKE OPTION I
MAGNETOMETER:	LIKE GOES I-M
XRS:	LIKE GOES I-M
SXI:	LIKE OPTION I
LOW ENERGY PLASMA:	LIKE OPTION I

*REDESIGNED STRUCTURE MAY BE REQUIRED TO MINIMIZE DEFOCUSING EFFECTS

Two spacecraft communications system configurations to implement a full four channel WEFAX capability were considered. One consisted of separate transmitters for each channel and the other consisted of one transmitter for all four channels. Both configurations use a common S-Band uplink receiver. The four separate transmitter configuration was selected for Option II because the

GOES-I WEFAX power amplifier can be used directly for each of the channels, thus minimizing cost and risk. The most notable effects of this change over the Option I system parameters are a 14 kg increase in spacecraft weight and a 150 W greater power consumption.

The final payload subsystem listed in the Option II column of the GOES-N Payload/Spacecraft Vehicle Matrix Table 1 that is changed over the Option I configuration is the DCS. Higher rate Data Collection Platform (DCP) transmissions at 300 and 1200 bps are being initiated in the GOES I-M time frame. The principal change from the Option I configuration is a 3 Db increase in Data Collection Platform Response (DCPR) downlink effective isotropic radiated power (EIRP), from 150 to 300 Mw, to provide increased margin for the higher rate DCP channels. No changes to either the CDA or the DCPs are required for the Option II changes. Greater detail on the DCS is contained in Section 11.4 of the GOES-N Report.

The payload changes for Option II result in potential weight increases that could exceed the load carrying capability of both the baseline and modified versions of the GOES I-M spacecraft structure. For this and other reasons, a different spacecraft was selected. Some principal spacecraft improvements desired for the Option II spacecraft are:

1. Increased payload weight capability (i.e., structural strength, fuel capacity)
2. Thermally and mechanically isolated sensor payload platform (an optical bench)
3. Minimal solar pressure disturbances

A review of current aerospace industry spacecraft revealed that the existing HS601 spacecraft design incorporates many of the features desired with only relatively minor modifications needed to address the GOES-N mission requirements. Although this spacecraft requires modifications to meet GOES-N requirements, they are state-of-the-art changes. Therefore, this HAC bus was chosen as the basis for Options II and III.

Internally, the HS601 bus needs few modifications because it is already structurally able to carry the full-up Atlas IIAS capability of 7500 lb. The propulsion tanks can carry fuel for 7 years capability even with the maximum GOES-N Option III payload. Sufficient battery power to allow full eclipse operation is easily provided in the existing design. Most of the internal modifications will consist of and be due to incorporating the Option II sensor electronics in place of the original payload of communication transponders and power supplies.

Twenty one HS601 have been ordered to date by various customers and nineteen are in various stages of construction.

The recommended control system is inertially referenced, using very stable gyros and star trackers to sense spacecraft roll, pitch, and yaw attitude. Pointing errors from all sources, including mirror motion, sensed by the star tracker/gyro system are processed by the attitude control electronics (ACE) to produce two sets of error signals for control of high and low frequency disturbances. The operation of this "closed loop" control system is expected to result in smaller pointing errors than the "open loop" system used on GOES I-M and Option I. The Option II/III elements are

based on designs utilized for many of Goddard's high precision pointing spacecraft such as International Ultraviolet Explorer (IUE), Solar Maximum Mission (SMM) and Landsat. Implementation risk should, therefore, be lower with the recommended system.

Unlike the Option I design in which the solar array panels are all deployed to the south, the Option II solar panels deploy in an east and west direction, thus minimizing solar pressure torques. Because the resultant solar pressure torque is manageable, the solar sail is eliminated, allowing the mission sensor coolers an unobstructed view of space.

Option II – Ground System and Spacecraft Communications

Option II includes the LMS, the additional three WEFAX channels (a second analog channel, a 19.2 kbps digital WEFAX channel, and a 50 kbps data channel), an improved imager, a high spectral resolution sounder, a slightly higher effective isotropic radiated power DCP report channel, and the GOES–I S&R subsystem. In addition, a two–station ranging capability is needed to meet control system orbit determination accuracy requirements.

The total data rate of the Option II instruments, exclusive of processed (GVAR) data relay is about 12 Mbps, compared to under 3 Mbps for Option I. The majority of this data rate increase is due to the sounder. Accommodation of this data rate within the 20 Mhz band allocated at S-Band requires the use of compression techniques for the imager and sounder data and balanced Quadraphase Shift Keying modulation. Thus, an on–board multiplexer is needed to combine imager and sounder data, and the instruments need the capability to compress data and forward-error–correction encode the data. The LMS and attitude control system (ACS) data could be downlinked directly to the Satellite Operations Control Center (SOCC) and Data Utilization Station (DUS) via the Multiuse Data Link (MDL), along with telemetry data and the other SEM instrument data, avoiding the need to relay the LMS and control system data via the GOES variable data format (GVAR) link. An on–board multiplexer would also be required for this link to combine the various data streams. Associated demultiplexers would be required at the receiving ground stations.

In addition to the above changes to the spacecraft and ground station equipment, the following communication system improvements, some of which were included in Option I, are also considered for Option II.

1. Eliminating the MDL and CDA on–orbit telemetry transmitters by multiplexing these data streams with the imager and sounder data on the sounder data link (SDL).

2. Combining the DCP report band with one of the WEFAX channels to reduce intermodulation products within the DCP report band, thus improving performance and eliminating DCP report transmitters. The effect on the WEFAX signal effective isotropic radiated power would be a reduction of less than 0.5 Db and would require no changes to the ground system.

3. Eliminating the processed data relay (GVAR) link, feasible if GVAR users can use remapped products distributed via the Advanced Weather Information Processing System (AWIPS).

Option II – Risk Identification (Table 3)

The spacecraft structure, thermal, power, and propulsion subsystem designs, like Option I, are based on a system that does not yet have flight experience. However, the HS601 series development is somewhat more mature than the Space Systems Loral GOES–I, because the first one is scheduled for launch about a year earlier than GOES–I, and because four to six times as many HAC units are already in various stages of construction and test.

The increase in risk associated with imager improvements is small, because those changes do not require a change in the GOES I–M design (e.g., cooler). Performance risk should decrease with the incorporation of the more accurate optical encoder mirror drive, reliably used on all of the preceding GOES series.

TABLE 3: FEASIBILITY, RISK, SCHEDULE MATRIX

	FEASIBILITY	RISK	SCHEDULE	COST[1]	PERFORMANCE
REPLICATE GOES I-M	FEASIBLE, OPERATIONAL NO R&D	SAME AS GOES–M	SAME AS GOES–M	N = M	GOES–M
OPTION I (EVOLUTIONARY)	FEASIBLE, OPERATIONAL NEEDS SOME DEVELOPMENT	SLIGHTLY LESS THAN GOES–M	SAME AS GOES–M	SMALL INCREASE OVER REPLICATION	SLIGHTLY BETTER THAN GOES–M, MORE RELIABLE
OPTION II PRIOR R&D	UNKNOWN OUTCOME FOR DEVELOPMENTAL INSTRUMENTS (e.g.,SOUNDER)	SOME RISK FOR OPERATIONAL MISSION NEEDS PROTO-FLIGHT OF INSTRUMENTS	SCHEDULE: 96 MONTHS TO LAUNCH	LOWER COST THAN WITH NO DEVELOPMENT	MORE CORE AND OPTIONAL NOAA REQUIREMENTS MET
OPTION II NO PRIOR R&D	INCLUDE R&D IN PHASES–B & C/D, UNKNOWN OUTCOME	MORE RISK THEN OPTION II ABOVE	138 MOS. TO LAUNCH 48 MOS. PROTO C/D 42 MOS. ENGR. C/D 30 MOS. PROC. 18 MOS. PHASE–A/B	HIGHER COST	
OPTION III PRIOR R&D **OPTION III NO R&D**	SAME AS OPTION II ABOVE BUT HIGHER RISK AND COST BUT GREATER PERFORMANCE POTENTIAL			HIGHER COST	MORE OPTIONAL AND ENHANCED NOAA REQUIREMENTS MET
REPLICATE GOES–7	FEASIBLE	GOOD: SAME AS GOES–7 AND/OR GMS	60 MONTHS TO LAUNCH 42 MOS. PHASE–C/D 18 MOS. PROC.	MINIMUM NON–RECURRING	MAINTAIN CURRENT SERVICES WITH LESS PERFORMANCE THAN GOES I–M

[1] COST INFORMATION IN VOLUME 3

In contrast to the imager, the Michelson sounder is a new development for this application. The larger optics adds some increased risk because of the greater difficulty required to maintain optical quality and scan efficiency. This approach is judged less risky than smaller optics and the unknowns of a mechanical refrigerator system. Elimination of the solar sail and the addition of semi-yearly 180 degree yaw maneuvers will enhance the effect of the cooler and lessen performance risk somewhat.

Changes to the WEFAX and DCS involve adding channels to existing designs. The methods proposed for implementing this additional capability in the Option II configuration require minimal changes to the existing hardware design and has very little impact on ground systems. With the exception of the HSRS, the Option II risk can be quantified to be nearly the same as Option I and GOES I-M. However, the risk of a completely successful development of the interferometer sounder for geosynchronous operational use is high, in terms of both performance and reliability.

Option II - Launch Vehicle

The Atlas IIA was selected for launch of the Option II concept. Improvements in the WEFAX, control system, a new sounder, and an additional sensor, the LMS, have caused the weight and power requirements to increase over Option I. These increased needs require additional stationkeeping fuel and solar array and battery capacity. When all improvements and supporting capacities are accounted for, the Option II configuration weight estimate is 2602 kg, 440 kg greater than Option I but still within the lift capability of Atlas II, which is 2680 kg. However, a 78 kg margin is grossly inadequate at the outset of a program, especially when the program requires the development of two new instruments, such as the sounder and LMS; ergo, the selection of Atlas IIA. With the Atlas IIA for launch, the margin is estimated to be 208 kg.

OPTION III RESULTS

The Option III concept continues the theme of evolutionary improvement over Option II by incorporating essentially the same spacecraft, control system, sounder, WEFAX, DCS, S&R and SEM instruments. While the improvements and additions increase implementation risks and costs, they also significantly increase performance capability.

The advanced imager is a totally new design that incorporates all the additional spectral bands requested by NOAA and meets, in most cases, the desired spatial resolution for each band. Perhaps the most significant change is the use of very low temperature coefficient materials (such as Graphite Fiber Reinforced Plastic (GFRP)) in the construction of the imager combined with more efficient structural geometry to lessen the pointing errors caused by diurnal thermal distortion. Not only will the use of GFRP minimize thermal deformation and/or thermal snapping, it also helps to raise the lowest fundamental structure frequency mode out of the instrument mirror servo controller bandwidth, thus enabling the design of a more stable controller.

Another significant change is the use of spatial separation for IR spectral channels in a common extended focal plane rather than spectral separation by beam splitters as implemented on GOES-I. This method greatly enhances the chances of maintaining fundamental co-registration accuracy

OPTION III

TASK:

- SYSTEM DESIGN CHANGES TO ESSENTIALLY SATISFY ENHANCED NOAA REQUIREMENTS

RESULTS:

- FEASIBILITY: CONTINGENT UPON REQUIREMENTS CHANGES & PRIOR DEVELOPMENT OF INSTRUMENTS AND SPACECRAFT COMPONENTS
- RISK: HIGH. SUITABLE FOR OPERATIONAL USE IF INSTRUMENT AND SPACECRAFT DEVELOPMENT OCCURS
- SCHEDULE:VARIABLE DEPENDING ON DEVELOPMENT BEING SEPARATE OR INCORPORATED IN PHASE-B,C,D
- COST: HIGH NON-RECURRING, HIGHER RECURRING (COMPARED WITH OPTION II)
- TASK EVOLVED INTO SATISFYING MORE CORE, OPTIONAL, AND ENHANCED REQUIREMENT THAN OPTIONS I AND II

SPACECRAFT (DIFFERENT BUS):

- IRU SYSTEM (STAR SENSOR/GYROS) - 10μr (SAME AS OPTION II)
- IMPROVED INR COMPARED TO OPTION II - NEW INSTRUMENTS (THERMAL/STRUCTURAL)

PAYLOADS:

NEW IMAGER:	ADDRESSES ENHANCED REQUIREMENTS (1.0KM VIS, 4.0KM @10.7μm)
AUX. SOUNDER:	OR EQUIVALENT CAPABILITY
LIGHTNING MAPPER:	LIKE GOES-M PROPOSAL, MODIFY FOR LOW LIGHT IMAGING OPERATIONS, WITH 10KM IFOV
ADV. SOUNDER:	HIGH SPECTRAL RESOLUTION (WITH MECHANICAL REFRIGERATOR)
WEFAX:	ADDITIONAL CHANNELS (SAME AS OPTION II)
DCS:	(SAME AS OPTION II)
S&R:	GOES I-M - NO LOCATION CAPABILITY
SEM:	

EPS:	OPTION I IMPROVEMENT
MAGNETOMETER:	GOES I-M
XRS:	GOES I-M
SXI:	OPTION I (AS PROPOSED FOR GOES-M)
LOW ENERGY PLASMA:	OPTION I (NEW)
SOLAR MAGNETOGRAPH:	NEW (INCLUDES H-ALPHA IMAGER)
TOTAL ELECTRON COUNT:	NEW

during the fabrication process and in the operational thermal environment. However, it aggravates the problems of image rotation. It is a serious error source requiring correction in navigation and within-frame registration performance in the GOES-I concept, even with the smaller focal planes used there. Another significant change to the advanced Option III imager, therefore, is to eliminate image rotation by incorporating separate scan mirrors for the east-west and north-south

axes. Along with this dual mirror scanner, operation in orbit at very small inclinations (0.05 degree or less) and resampling of the image data in ground processing would likely result in minimizing channel-to-channel misregistration.

A major difference in the Option III payload is the addition of an "auxiliary" imager. Its purpose is to provide continuous full-disk images. This would allow the advanced imager to continuously concentrate on a limited areal coverage mode to observe localized mesoscale events. This instrument would also provide a redundant imaging capability in the event of a primary imager failure. Several suggestions have been made for the source of the auxiliary imager including an Indian satellite (INSAT), GOES-I, or an Applications Technology Satellite (ATS-6) Geosynchronous Very High Resolution Radiometer (GVHRR) type imager. An alternate approach to the auxiliary imager is to double the number of visible channels in the primary imager and activate the redundant IR detectors so that it can cover the full-disk earth in half the time, thus freeing the remaining time for partial disk imaging.

The sounder optical aperture has been reduced back to GOES I-M size, and a mechanical cooler system is used to improve radiometric performance. The focal plane is cooled by a Stirling cycle cooling system modeled after the units planned for the Atmospheric Infrared Sounder (AIRS) instrument on the Earth Observing System (EOS). (Note: the focal planes of the Option III imager remain passively cooled.) The Option III instrument weighs approximately the same as the Option II unit because the smaller optics weight is nearly offset by the mechanical cooling system. However, increased power requirements and control electronics for the refrigerator do significantly increase the Option III sounder system weight.

The final major payload difference from the Option II configuration is in the SEM area. Option III has an additional two instruments in the SEM package, a combination SVM/HαI and a radio beacon for measuring total electron content (TEC). The Solar Vector Magnetograph/Hydrogen-Alpha Imager (SVM/HαI) is a technically challenging instrument for GOES and should be subjected to a full Phase-A study. To sense the magnetic fields at the photosphere of the sun, even with state-of-the-art detectors, requires co-registering multiple images to better than the pixel size of 1 arc sec over at least a 5 minute period for the needed sensitivity. This will require very sophisticated optics along with very precise platform servo control. Added to these already tough requirements is the necessity to do narrow band sensing measurements in multiple spectral bands if the Hα requirements are to be realized in the same instrument.

A Very High Frequency/Ultra High Frequency (VHF/UHF) radio beacon will be used to monitor the Total Electron Content sensor along the line of sight between the spacecraft and a ground station. The technique will be to measure the differential group delay of a code sequence transmitted at two frequencies in the VHF/UHF radio bands. This technique is very simple to implement on the Option III bus. Because the U.S. Air Force (USAF) has already implemented a similar capability on the globally distributed multiple Global Positioning System (GPS) spacecraft, NOAA may not require a similar capability on GOES-N.

The Option III spacecraft is almost identical to the Option II spacecraft (modeled after the HAC HS601). Internally, the only differences are in the size of the fuel tanks (38 versus 35 in), data processing equipment to handle the combination SVM/HαI instrument, three radiometers (two

imagers, one sounder) instead of two, increased power handling and storage, and more communications equipment. Externally, the solar array is larger and the optical bench is configured differently to accommodate the three radiometers. The basic structure of the Option III spacecraft is not changed over Option II nor are the elements of the control system.
Option III - Ground System and Spacecraft Communications

The total data rate of the Option III instruments, exclusive of processed (GVAR) data relay, is about 14 Mbps. Accommodation of this data rate within the 20 Mhz S-band allocation requires compression of the imager, auxiliary imager, and sounder data. The use of a bandwidth efficient modulation scheme for the SDL, such as 8-PSK (Phase Shift Keying), is needed to reduce the channel bandwidth required. An on-board multiplexer is also needed to combine the imager, auxiliary imager, and sounder data into one data stream for input to the sounder data link modulator. Data from the remaining instruments would be transmitted via the MDL, as in Option II.

Because of the added instruments and higher instrument data rates, new center frequencies are needed for the SDL, MDL, and GVAR links. On-board multiplexors are needed for the sounder data link and MDL. For the ground stations, an 8-PSK demodulator is needed at the CDA to demodulate the sounder data link signal. A new Quadraphase Shift Keying modulator plus multiplexer is required at the CDA to transmit GVAR data. New Quadraphase Shift Keying demodulators and demultiplexers are required at all stations receiving the GVAR signal.

In addition to the above changes to the spacecraft and ground station equipment, communication system improvements (which were described for Option II) are also considered.

Option III - Risk Identification (c.f. Table 3)

The risk of successfully developing, implementing, and operating the proposed Option III configuration is significantly greater than either of the two previous options. Development risk is up primarily because of the new imager, sounder mechanical cooler, and SVM/Hαl designs. Implementation risk is higher because of the addition of a second imager and the SVM/Hαl. Operational risk increases because of the complex dynamic interactions between the spacecraft and the various additional moving masses, such as the dual mirrors in the imager, the auxiliary imager mirror, the sounder mirror, the sounder mechanical refrigerators, and the additional SVM/Hαl weight on the moving solar panel yoke.

The net result of these increased risks shows up in a longer schedule and a higher cost for the Option III program. Considering the new imager, some of the risks of a new design are offset by incorporation of proven concepts. The single axis per mirror concept has been well proven on all previous GOES spacecraft. Using GFRP, with its hygroscopic tendencies, for most of the imager structure is a new concept that may be challenging to implement, but the offsetting potential performance gains can be enormous in the areas of thermal deformation and structural frequency response. Spatially separating the IR spectral channels in a common extended focal plane and eliminating numerous beam splitters eases the usual internal alignment problems and greatly enhances the chances of maintaining fundamental co-registration accuracy during the operational thermal environment.

The risk inherent in the sounder is as described for Option II with the additional risk of mechanical cooler implementation. The unknowns are basic refrigerator reliability and lifetime and the effect of mechanical vibrations on Image, Navigation, and Registration errors. By the time GOES-N would need refrigerators, the concept may have been space proven by the EOS program. Offsetting the refrigerator risks are the potential for greatly enhanced sounding performance through lower focal plane temperatures and smaller, more accurate, optics.

The risk of building an SVM/HαI capability, both housed in a package of reasonable size and weight, is quite large. The multiple image co-registration accuracy required combined with the larger weight carried on the solar pointing platform, increase concerns that dynamic interactions with the spacecraft control system may adversely affect Image, Navigation, and Registration system errors.

The top of the line Atlas IIAS is required for launch of the Option III configuration. This is primarily due to the additional payload weights of the new imager, a second imager, the sounder mechanical refrigeration system, and the combination SVM/HαI. To support this heavier payload, larger fuel tanks and solar arrays are also required. The total Option III weight is estimated to be 2974 kg, which is 372 kg heavier than Option II and 812 kg heavier than Option I. The Atlas IIAS has a launch to Geosynchronous Transfer Orbit (GTO) payload capacity of 3490 kg, resulting in a very adequate "start of program" margin of 516 kg.

RECOMMENDATIONS AND CONCLUSIONS

The state-of-the-art of meteorological prediction and the utilization of models in this process are evolving rapidly. Consequently, the 1989 NOAA requirements for GOES-N are more advanced than the 1983 NWS requirements for GOES I-M. Further, it has been recognized that not all the originally specified GOES I-M requirements will be met. Therefore, NOAA recognized the need for a new look at a more advanced geosynchronous mission than the I-M series and subsequently requested a GOES-N study to examine what is feasible for meeting the advanced requirements listed in Appendices 1 through 6.

The "evolutionary" basis of the study resulted in system concept Options I, II, and III. The three options were designed to meet increasingly difficult levels of NOAA Core, Optional, and Enhanced requirements. The requirements are summarized in Appendices 1 through 6, categorized by imagers, sounders, SEM, DCS, WEFAX, and S&R. One major result of the study was the identification of a significant number of requirements that can be met as a function of the three options. The NOAA requirements entail the use of sensor and spacecraft systems that are currently beyond the state-of-the-art. This situation may change if development of "tall pole" instruments and spacecraft subsystems is initiated now. If the "preferred" approach (precursor and ongoing R&D) is adopted, then more NOAA requirements will be satisfied by the next operational GOES series.

The "unmet" NOAA requirements are listed, versus proposed options, in Table 2. About 20 requirements are indicated as being partially or totally not met. The reasons for the "unmet" requirements, another output of this study, are presented in Appendix 10. Important INR, sounding rate, imager radiometric performance, SEM, S&R, and DCS "unmet" requirements are

crucial to NOAA operations in the GOES-N time frame. These requirements and their associated system elements need to be revisited prior to Phase-B. The SEM Solar Vector Magnetograph and the Hydrogen-alpha Imager require full development.

TASK I COST STUDY VALIDITY

GOES I-M developments, unknown in 1989 when the GOES I-M replication cost study was completed, indicate that an updated study report would be more valid. This has been reported to NOAA, and work is currently in process relative to this effort.

Recommended Next Steps for GOES-N

In order to proceed with the development of the GOES-N system, the following steps need to take place:

1. Change NOAA requirements so that a single option (I, II, III, or hybrid) or "point design" can feasibly meet them. NOTE: this activity is currently underway for the imager and sounder.

2. Initiate a development program which addresses the "tall poles" of the selected design thrust. This can be a NASA, NOAA, or joint effort.

3. Because the Phase-A study was not completed, conduct a pre-Phase-B study of the "point design" to reassess and identify "tall poles."

4. Generate enough information to prepare the RFP for competitive parallel Phase-B studies such that they are valid contractual arrangements in the sense that they produce m[illegible] accurate cost estimates for Phase-C/D and allow the government to initiate a realistic Phase-C/D. Phases A, B, C/D represent a continual learning process for the government and contractors and allows all parties to know what is being "bought and sold." These are the necessary ingredients for a productive business arrangement.

INFLUENCE OF NASA R&D ON OPTIONS II AND III

The successes or failures of most GSFC research missions have proven directly related to research and development activities preceding flight programs and to adequate Phases-A and B preceding Phase-C/D. Section 8 describes in more detail, the events leading to the curtailment of NASA R&D involvement in the nation's weather satellite programs. As the need for this meteorological capability increases due to population growth and emerging environmental factors, a corresponding stronger need for R&D, research flights, and protoflights is becoming evident.

Options II and III are, therefore, deemed "feasible" provided the prerequisites described above are accomplished first. Independent RAO cost studies for Options I, II, and III show markedly decreased cost estimates for the R&D based "preferred strategy."

PHASE-A STUDY

A complete Phase-A study based on NOAA requirements is deemed necessary. Section 8 contains study and other recommendations for the spacecraft, instruments, and the total GOES-N system. The postponement of these studies, normally conducted during this phase, to Phase-B has not proven optimally successful.

GOES I-M BASIS FOR GOES-N STUDY

The results of this study have been, by direction, based on the GOES I-M system. As the study developed, some of the basic GOES I-M premises were changed and GOES-N results based on these premises were also changed. Even as the GOES-N report was being written, additional baseline changes created an aura of uncertainty with regard to some results and recommendations.

INSTRUMENT PROCUREMENT STRATEGY

The normal GSFC mode of direct procurement of instruments for satellite flights has proven practical, economical, and more reliable. The same procurement/management strategies employed for NASA research missions are recommended for operational missions, built by NASA, for other agencies of the government .

APPENDIX 1: GOES-N IMAGER REQUIREMENTS SUMMARY

AREA	CORE	OPTIONAL	ENHANCEMENTS
SPECTRAL BAND & SPATIAL RESOLUTION	RC1 (met) 0.55 – 0.75 μm – 1km 3.8 – 4.0 μm – 4km 6.5 – 7.0 μm – 8km 10.1 – 11.2 μm – 4km 11.5 – 12.5 μm – 4km	RO1 INCREASE RESOLUTION 3.8 – 4.0 μm – 2km 6.5 – 7 μm – 4km ADD SPECTRAL BANDS 0.86 μm – 4km 1.6 μm – 4km 7.3 μm – 4km 13.3 μm – 4km	RE1 0.55 – 0.75 μm – 0.5km
EARTH LOCATION ACCURACY DAY (NOON ± 8 HOURS) NIGHT (MIDNIGHT ±4 HOURS)	RC2 (met) 4km (3σ) – NADIR 6km (3σ) – NADIR	RO2 (met) 2km (3σ) – 45° LATITUDE 2km (3σ) – 45° LATITUDE	
REGISTRATIONS:			
PIXEL-TO-PIXEL	RC3 –42 μr (3σ) – INCLINATION ≤0.1° –48 μr (3σ) – INCLINATION ≤0.5°	RO3 –14 μr BETWEEN ANY TWO PIXEL	
CHANNEL-TO-CHANNEL	RC4 0.5 km (3σ) AT NADIR (14μr)		
IMAGE-TO-IMAGE DAY NIGHT	RC5 (met) 42 μr (3σ)–15 Minute 84 μr (3σ)–90 Minute 70 μr (3σ)–15 Minute 105 μr (3σ)–90 Minute	RO5 14 μr (3σ)–90 Minute 14 μr (3σ)–90 Minute	
TEMPORAL RESOLUTION AND COVERAGE	RC6 (met) FULL DISK – ≤30 Minute 3000 X 3000 km – ≤5 Minute 1000 X 1000 km – ≤2 Minute		

GOES-N IMAGER REQUIREMENTS SUMMARY (continued)

AREA	CORE	OPTIONAL	ENHANCEMENTS
SENSITIVITY & DYNAMIC RANGE	RC7 (met) -3.8-4.0 µm-NEDT OF 1.4K @ 300K -6.5-7.0 µm-NEDT OF 1K @ 230K -10.2-11.2 µm-NEDT OF 0.35K @ 300K (ALSO 1.4K @ 200K) -11.5-12.5 µm-NEDT OF 0.35K @ 300K	RO7 -3.8-4.0 µm-NEDT OF 0.1K @ 300K -6.5-7.0 µm-NEDT OF 0.3K @ 240K -10.2-11.2 µm-NEDT OF 1.0K @ 300K -11.5-12.5 µm-NEDT OF 0.1K @ 300K	RE7 INCREASED DYNAMIC RANGE FOR IR WINDOW CHANNELS TO 350K
CLOUD SMEARING	RC8 IMAGER OUTPUT TO BE WITHIN 0.02 OF IT FINAL TRUE VALUE WITHIN 1 IGFOV		
CHANNEL-TO-CHANNEL SIMULTANEITY	RC9 (met) COINCIDENT DATA COVERING 8X8km AREA WITHIN 5 SEC		
TIMELINESS	RC10 (met) MAX. DELAY OF 30 SEC BETWEEN DATA ACQUISITION AND TRANSMISSION		
IMPROVED PERFORMANCE		RO11A (met) -REDUCE RECOVERY TIME AFTER SPACECRAFT MANEUVERS TO 1 HR -MIDNIGHT PERFORMANCE SHOULD APPROACH DAYTIME PERFORMANCE RO11B (met) -MINIMUM OF SINGLE WINDOW IR CHANNEL DURING ECLIPSE	
ENCIRCLED ENERGY (BLURRING)		RO12 ADD SPECIFICATION	
VISIBLE CALIBRATION			RE13 CALIBRATE VISIBLE CHANNEL
NIGHT VISIBLE			RE14 ADD LOW LIGHT CAPABILITY AT NIGHT
CONFLICTS			RE15 ADDITIONAL IMAGER FOR BACKUP AND TO RESOLVE SCHEDULE CONFLICTS (RESOLUTION-2km VIS.; 6km IR)
LIGHTNING MAPPER		RO16 ADD LIGHTNING MAPPER	

APPENDIX 2: GOES-N IMAGER REQUIREMENTS SUMMARY (CORE/REMEDIAL)

CHANNEL NUMBER	SPECTRAL RANGE (μm)	SPATIAL RES. (km)	BRIGHTNESS/ THERMAL SENSITIVITY (S/N or NEDT)	DYNAMIC RANGE	PRINCIPAL APPLICATIONS
1	0.55 – 0.75	1	3:1 AT 0.5% ALBEDO	0–100% ALBEDO	WEATHER MONITORING; SEVERE STORM DETECTION; CLOUD MAPPING, TYPING, AND MOTION; SNOW COVER; INSOLATION; (CLOUD FILTER)
2	3.80 – 4.00	4	1.4K AT 300K	4–320K	NIGHT TIME CLOUD DETECTION AND H_2O VAPOR ESTIMATES
3	6.50 – 7.00	8	1.0K AT 230K	4–320K	JET STREAM LOCATION AND UPPER ATMOSPHERIC CIRCULATIONS (WATER VAPOR)
4	10.20 – 11.20	4	1.4K AT 200K 0.35K AT 300K	4–320K	DAY/NIGHT SURVEILLANCE OF CONVECTION STORMS, LOW LEVEL MOISTURE, SURFACE TEMPERATURES, WINDS, SOIL MOISTURE (THERMAL INERTIA)
5	11.50 – 12.50	4	0.35K AT 300K	4–320K	LOW LEVEL WATER VAPOR & SURFACE TEMPERATURES

APPENDIX 3: GOES-N SOUNDER REQUIREMENTS SUMMARY

AREA	CORE	OPTIONAL	ENHANCEMENT
CHANNELS	RC17 (met) SAME AS GOES I-M SOUNDER @ 8KM	RO17 HIGH SPECTRAL RESOLUTION SPECTROMETER OR INTERFEROMETER (4-15μm) WITH 8km RESOLUTION	
CLOUD DETECTION	RC18 (met) VISIBLE @ 8KM	RO18 -DAY--VISIBLE CHANNEL WITHIN 1km RESOLUTION -NIGHT--IR WINDOW WITH 2km RESOLUTION	
MEASUREMENT ACCURACY	SEE TABLE RC17-1		
TEMPERATURE	RC19 (met) 1000-700mb-±2K 700-300mb-±1.5K 300-100mb-±2.5K	RO19 ALL LEVELS-±1K	
HUMIDITY	RC19 (met) 1000-600mb-±20% RH 600-200mb-±15% RH	RO19 ALL LEVELS ±1.5-3K DEW POINT	
SENSITIVITY	RC20 (met) A SOUNDING FOR EACH 60X60km AREA USING 9 CLEAR PIXELS	RO20 SINGLE PIXEL SOUNDING	
SPATIAL RESOLUTION	RC21 (met) ≤ 8KM		RE21 ≤ 4KM
TEMPORAL RESOLUTION & COVERAGE	RC22 (met) -3000 X 3000 km IN ≤ 30 Minute -1000 X 1000 km IN ≤ 10 Minute	RO22 -3000X3000 km IN ≤ 40 Minute (SEE RC22) -SOUNDING IMAGE PRODUCTS-2500X2500km IN≤ 20 Minute TEMP. ACCURACY DEGRADED BY 50%	RE22 (met) INCREASE IN EFFECTIVE DWELL TIMES BY FACTORS OF 2 AND 4
EARTH LOCATION ACCURACY	RC23 (met) ≤4KM (3σ) ABSOLUTE		
PIXEL-TO-PIXEL	RC24 (met E/W) 0.1 IGFOV BETWEEN ADJACENT IGFOV'S (0.2 N/S)		

GOES-N SOUNDER REQUIREMENTS SUMMARY (continued)

AREA	CORE	OPTIONAL	ENHANCEMENTS
CHANNEL-TO-CHANNEL	RC25 -RADIOMETRIC RESPONSE CENTROIDS MATCHED WITHIN 2% OF TOTAL IGFOV WIDTH (1σ) HALF-POWER IGFOV CHANNEL WIDTHS WITHIN 1% (1σ)	RO25 -CO-REGISTER CLOUD DETECTION VISIBLE & IR DATA WITHIN 14 μr (3σ) -ALL IGFOV'S MATCHED TO WITHIN 2% (1σ)	
IMAGE-TO-IMAGE	RC26 (met) WITHIN 1 IGFOV (3σ)		
SPECTRAL RESPONSE	RC27 (met) - 72% OF AREA UNDER SPECTRAL RESPONSE CURVE SHOULD LIE WITHIN THE SPECTRAL BANDPASS -96% OF AREA SHOULD LIE WITHIN TWICE SPECTRAL BANDPASS -TOTAL AREA WILL BE ALL NON-ZERO RESPONSES OF 1% OR GREATER OF MAX PEAK		
ENCIRCLED ENERGY	RC28 (met) -70% OF ENERGY WITHIN IGFOV -83% OF ENERGY WITHIN 10km (1.25 IGFOV WITH 8km IGFOV)		
ELECTRICAL CROSSTALK *	RC29 (probably met) PIXEL-TO-PIXEL MEMORY OF $\leq$0.25 NEDT		
QUANTIZING	RC30 (met) LEAST SIGNIFICANT BIT= 0.5 NEDT		

* Does not include diffraction effects

APPENDIX 4: GOES-N SEM REQUIREMENTS SUMMARY

AREA	CORE	OPTIONAL	ENHANCEMENTS
ENERGETIC PARTICLES	RC31 PROTONS AND ALPHAS 30keV >700MeV per NUCLEON ELECTRONS $\leq$ 30keV - 4MeV HEAVY IONS FLUENCE ($Z \geq 3$)	RO31 (met) ELECTRONS AND POSITIVE IONS 10eV - 30keV	
MAGNETIC FIELDS	RC32 (met) 3 COMPONENTS OF THE VECTOR FIELD TO $\leq$ 1nT ACCURACY		
TOTAL ELECTRON CONTENT		RO32 (met) IONOSPHERIC RADIO BEACON MEASURES POLARIZATION ROTATION AT VHF	
SOLAR OBSERVATIONS	RC33 (met) FULL-DISK X-RAY SENSOR FLUX IN 0.5 - 4 AND 1 -8 ANGSTROM BANDS	RO33 SOLAR EUV SPECTROMETER TIME INTEGRATED FLUX IN SEVERAL SPECTRAL LINES	
	RC34 (met) SOLAR X-RAY IMAGER CORONA IMAGES IN SEVERAL BANDS	RO34 * SOLAR MAGNETOGRAPH PHOTOSPHERIC VECTOR FIELD IN EACH ACTIVE REGION WITH 2.5mT SENSITIVITY	
		RO35 * SOLAR HYDROGEN ALPHA LINE IMAGER HIGH FRAME RATE (1 MINUTE) SOLAR IMAGES IN HYDROGEN ALPHA LINE & CONTINUUM	

* These instruments require full development

APPENDIX 5: GOES-N DCS/WEFAX REQUIREMENTS

AREA	CORE	OPTIONAL	ENHANCEMENTS
DATA COLLECTION SYSTEM (DCS)	RC36 INTERROGATES PLATFORMS & RECEIVES DATA FROM THESE & OTHER NON-INTERROGABLE PLATFORMS (met) CHANNEL CAPACITY = 266 266 CHANNELS AT 100 OR 300 BAUD 40 CHANNELS AT 1200 BAUD DCS SHALL HAVE THE CAPABILITY TO EARTH LOCATE A TRANSMISSION		
WEFAX	RC37 CHANNEL 1 LOW RESOLUTION WEFAX A, ANALOG (met) CHANNEL 2 LOW RESOLUTION WEFAX B, ANALOG CHANNEL 3 HIGH RESOLUTION WEFAX, ANALOG AND DIGITAL CHANNEL 4 NOAA PORT PRODUCTS UNREDUCED POWER LEVEL DURING PERIOD OF SPACECRAFT ECLIPSE		

APPENDIX 6: GOES-N SEARCH AND RESCUE REQUIREMENTS

AREA	CORE	OPTIONAL	ENHANCEMENTS
SPACE SEGMENT	RC35 RECEIVE 406MHz UPLINK SIGNALS FROM ELT/EPIRBS FOR DISTRESS ALERTS (met) RELAY DISTRESS SIGNALS TO EARTH STATIONS AT 1544.5MHz (met) PROVIDE LOCATION DETERMINATION OF DISTRESS SIGNALS SOURCE TO $\leq$20km		
GROUND SEGMENT	RC35 HARDWARE NECESSARY TO RECEIVE & PROCESS SIGNALS RECEIVED FROM SPACECRAFT SOFTWARE NECESSARY TO PROCESS SIGNALS RECEIVED FROM SPACECRAFT & TO RECOVER TRANSMITTER LOCATION SYSTEM DESIGN TO INTERFACE WITH U.S. MISSION CONTROL		

APPENDIX 7: LIST OF GOES-N STUDIES

#	#	STUDY	DESCRIPTION	(SM)[1]	FUNDING STATUS[2]
60	1	SC1	MAGNETOMETER	3.0	U
15	2	SC2	IMPROVE EARTH SEN	4.0	F
49	3	SC3	SIM STA/HSE KEEP	3.6	U
42	4	SC4	7 YR LF,INC FOR NO N-S STA KP	3.0	F
71	5	SC5	ELIM 3 DEAD SCANS	3.0	U
40	6	SC6	CHANGE MOM WHLS (DRP LMD)	1.0	F
50	7	SC7	GRND TRANSMITTERS	4.0	U
65	8	SC8	STORE SPINNING	4.0	U
68	9	SC9	ADD COMPUTER	4.0	U
2	10	SC10	USE INERTIAL REF UNIT	4.0	F
48	11	SC11	S/C FLIP 180 deg	3.6	U
9	12	SC12	MOM WHEEL (MW) TACHOMETER	4.0	F
69	13	SD1	SOFT WHL MOUNTS	4.0	U
41	14	SD2	MOM WHEEL (MW) DYN BALANCE	1.0	F
17	15	SS1	INCHWORM CO-REGIS	2.0	F
10	16	SS2.1	CENTER IR DET	2.0	F
45	17	SS2.2	I-K SNDR CH-CH REGIS	1.0	U
35	18	SS3.1	DAY/NITE NAV	0.3	F
11	19	SS3.2	OPS ECLIPSE	0.1	F
5	20	SS4.1	SENSOR POINTING	2.0	F
59	21	SS4.2	VARIABLE E-W SAMPLE	1.0	U
8	22	SS4.3	COLLOCATE MOTOR/ENCODER	2.0	F
18	23	SS4.4	IMC/MMC BASED ON IRU	3.0	F
13	24	SS4.5	SERVO/2km at nadir	2.0	F
67	25	SS5.1	STIFFEN STRUCTURE	1.5	U
79	26	SS5.2	STRUCTURAL APPROACHES	4.0	U
78	27	SS5.3	SYS ENGINEER REGISTRATION	2.0	U
16	28	SS6	ADD VIS ARRAY TO SNDR	1.8	F
64	29	SS7.1	IMAGE PLANE IMC	2.0	U
31	30	SS7.2	DIGITAL PROCESSOR	2.0	F
25	31	SS7.3	SNDR NAVIGATION/SERVO	2.0	F
66	32	SS8	RAM SELF TEST	1.0	U
47	33	SS9	AUTO-COLLIMATION ALIGN	2.0	U
7	34	SS10	LOW EXPANSION MAT	2.0	F
20	35	SS11.1	FLEX PIVOTS	1.0	F
57	36	SS11.2	SERVO CURES	2.0	U
6	37	SS11.3	SERVO/2km at 45 DEGREE	3.0	F
62	38	SS12	OFF-AXIS OPTICS DESIGN	3.0	U
4	39	SS13	ENCIRCLED ENERGY	2.0	F
51	40	SS14	FASTER IMAGER	4.0	U
54	41	SS15	SPINNING IMAGER	4.0	U
24	42	SS16	ADD'L IMAGER	1.8	F
21	43	SS17.1	NEW SOUNDER	4.0	F
44	44	SS17.2	SENSITIVITY NEW SNDR	4.0	F

1. SM: Staff Months; 2. U: Unfunded; F: Funded

LIST OF GOES-N STUDIES (continued)

#	#	STUDY	DESCRIPTION	(SM)	FUNDING STATUS
76	45	SS18	19 TO 14 SND CHANNELS	0.5	U
75	46	SS19	IM STAB 42μr	1.5	U
27	47	SS20	CH-CH REG 14μr	1.0	F
74	48	SS21	IM-IM REG 42μr	3.0	U
73	49	SS22	IM SENSTVTY 1K NEDT	2.0	U
72	50	SS23	I-K SNDR SENSITIVITY	4.0	U
23	51	SS24	IM SENSITIV .1K NEDT	3.0	F
70	52	SS25	IM SENSITIV 350K MAX	0.8	U
26	53	SS26	CLOUD SMEAR (.02*FINAL)	2.3	F
14	54	SS27	LARGER SUNSHADE (MIDNIGHT)	1.5	F
36	55	SS28	VIS CALIBRATION	1.3	F
30	56	SS29	NITE VISIBLE	0.5	F
38	57	SS30	LIGHTNING MAPPER	0.3	F
56	58	SS31	LARGER COOLER (SOUNDER)	1.8	U
29	59	SS33	SNDR CONTEMP IR FOR NITE	1.0	F
34	60	SS34	SINGLE PIXEL SOUNDING	1.0	F
63	61	SS35	4KM SOUNDING	3.0	U
52	62	SS36	HIGH SPEED SOUNDING	1.0	U
12	63	SS37	SNDR CROSSTLK <.25*NEDT	0.5	F
39	64	SS38	IM-IM REG 14μr	4.0	F
53	65	SS39	AMBIENT IR TESTING	1.0	U
61	66	SS40	HIGH RESOLUTION IMAGING	2.0	U
19	67	SS41	LARGER COOLER IMAGER	2.5	F
58	68	SS42	IMPROVED INST REDUN	1.0	U
77	69	SS43	PIX/PIX REGIS (1μr/3μr)	0.0	U
55	70	SS44	WIDE FIELD TST COLIMATOR	3.0	U
33	71	SS45	SNDR VIS/IR REGISTRATION	4.0	F
32	72	SN1	IMGR GRND NAV/REG RESMPLR	4.0	F
46	73	ST1	IMGR/ERTH SEN SM BSPLT	1.0	U
37	74	SDCPS	DATA COLLECTION PLAT SYS	4.0	F
28	75	SWEFAX	WEATHER FACSIM BROADCAST	2.0	F
3	76	SSEM	SOLAR ENVIRON MONITORING	4.0	F
43	77	SPP&C	PRODUCTS PROCESS AND COMM	4.0	F
1	78	S/C-OP	STUDY S/C OPTIONS	12.0	F
22	79	SSAR	SEARCH AND RESCUE	2.0	F
80	80	SG1	GOES N IMPACTS (WORK STATION)	5.0	U
81	81	SG2	GOES N IMPACTS ON PREDICTION	10.0	U

APPENDIX 8: FUNDED GOES-N STUDIES IN PRIORITY ORDER

#	#	STUDY	DESCRIPTION	($M)
1	78	S/C-OP	STUDY S/C OPTIONS	12.0
2	10	SC10	USE INERTIAL REF UNIT	4.0
3	76	SSEM	SOLAR ENVIRON MONITORING	4.0
4	39	SS13	ENCIRCLED ENERGY	2.0
5	20	SS4.1	SENSOR POINTING	2.0
6	37	SS11.3	SERVO/2km at 45 DEGREE	3.0
7	34	SS10	LOW EXPANSION MAT	2.0
8	22	SS4.3	COLLOCATE MOTOR/ENCODER	2.0
9	12	SC12	MOM WHEEL (MW) TACHOMETER	4.0
10	16	SS2.1	CENTER IR DET	2.0
11	19	SS3.2	OPS ECLIPSE	0.1
12	63	SS37	SNDR CROSSTLK <.25*NEDT	0.5
13	24	SS4.5	SERVO/2km at nadir	2.0
14	54	SS27	LARGER SUNSHADE (MIDNIGHT)	1.5
15	2	SC2	IMPROVE EARTH SEN	4.0
16	28	SS6	ADD VIS ARRAY TO SNDR	1.8
17	15	SS1	INCHWORM CO-REGIS	2.0
18	23	SS4.4	IMC/MMC BASED ON IRU	3.0
19	67	SS41	LARGER COOLER IMAGER	2.5
20	35	SS11.1	FLEX PIVOTS	1.0
21	43	SS17.1	NEW SOUNDER	4.0
22	79	SSAR	SEARCH AND RESCUE	2.0
23	51	SS24	IM SENSITIV .1K NEDT	3.0
24	42	SS16	ADD'L IMAGER	1.8
25	31	SS7.3	SNDR NAVIGATION/SERVO	2.0
26	53	SS26	CLOUD SMEAR (.02*FINAL)	2.3
27	47	SS20	CH-CH REG 14μr	1.0
28	75	SWEFAX	WEATHER FACSIM BROADCAST	2.0
29	59	SS33	SNDR CONTEMP IR FOR NITE	1.0
30	56	SS29	NITE VISIBLE	0.5
31	30	SS7.2	DIGITAL PROCESSOR	2.0
32	72	SN1	IMGR GRND NAV/REG RESMPLR	4.0
33	71	SS45	SNDR VIS/IR REGISTRATION	4.0
34	60	SS34	SINGLE PIXEL SOUNDING	1.0
35	18	SS3.1	DAY/NITE NAV	0.3
36	55	SS28	VIS CALIBRATION	1.3
37	74	SDCPS	DATA COLLECTION PLAT SYS	4.0
38	57	SS30	LIGHTNING MAPPER	0.3
39	64	SS38	IM-IM REG 14μr	4.0
40	6	SC6	CHANGE MOM WHLS (DRP LMD)	1.0
41	14	SD2	MOM WHEEL (MW) DYN BALANCE	1.0
42	4	SC4	7 YR LF,INC FOR NO N-S STA KP	3.0
43	77	SPP&C	PRODUCTS PROCESS AND COMM	4.0
44	44	SS17.2	SENSITIVITY NEW SNDR	4.0

APPENDIX 9: UNFUNDED GOES-N STUDIES IN PRIORITY ORDER

#	#	STUDY	DESCRIPTION	(\$M)
45	17	SS2.2	I-K SNDR CH-CH REGIS	1.0
46	73	ST1	IMGR/ERTH SEN SM BSPLT	1.0
47	33	SS9	AUTO-COLLIMATION ALIGN	2.0
48	11	SC11	S/C FLIP 180 deg	3.6
49	3	SC3	SIM STA/HSE KEEP	3.6
50	7	SC7	GRND TRANSMITTERS	4.0
51	40	SS14	FASTER IMAGER	4.0
52	62	SS36	HIGH SPEED SOUNDING	1.0
53	65	SS39	AMBIENT IR TESTING	1.0
54	41	SS15	SPINNING IMAGER	4.0
55	70	SS44	WIDE FIELD TST COLIMATOR	3.0
56	58	SS31	LARGER COOLER (SOUNDER)	1.3
57	36	SS1[illegible].2	SERVO CURES	2.0
58	68	SS42	IMPROVED INST REDUN	1.0
59	21	SS4.2	VARIABLE E-W SAMPLE	1.0
60	1	SC1	MAGNETOMETER	3.0
61	66	SS40	HIGH RESOLUTION IMAGING	2.0
62	38	SS12	OFF-AXIS OPTICS DESIGN	3.0
63	61	SS35	4KM SOUNDING	3.0
64	29	SS7.1	IMAGE PLANE IMC	2.0
65	8	SC8	STORE SPINNING	4.0
66	32	SS8	RAM SELF TEST	1.0
67	25	SS5.1	STIFFEN STRUCTURE	1.5
68	9	SC9	ADD COMPUTER	4.0
69	13	SD1	SOFT WHL MOUNTS	4.0
70	52	SS25	IM SENSITIV 350K MAX	0.8
71	5	SC5	ELIM 3 DEAD SCANS	3.0
72	50	SS23	I-K SNDR SENSITIVITY	4.0
73	49	SS22	IM SENSTVTY 1K NEDT	2.0
74	48	SS21	IM-IM REG 42μr	3.0
75	46	SS19	IM STAB 42μr	1.5
76	45	SS18	19 TO 14 SND CHANNELS	0.5
77	69	SS43	PIX/PIX REGIS (1μr/3μr)	0.0
78	27	SS5.3	SYS ENGINEER REGISTRATION	2.0
79	26	SS5.2	STRUCTURAL APPROACHES	4.0
80	80	SG1	GOES N IMPACTS (WORK STATION)	5.0
81	81	SG2	GOES N IMPACTS ON PREDICTION	10.0

APPENDIX 10: REASONS FOR UNMET NOAA REQUIREMENTS

TECHNICAL/STATE-OF-THE-ART

RC3/RO3: PIXEL-PIXEL REGISTRATION

- MECHANICAL INSTABILITIES & NON-LINEARITIES

RC5/RO5: IMAGE-IMAGE REGISTRATION

- OVERALL LIMITATION FROM COMBINATION OF INSTRUMENT POINTING, SPACECRAFT CONTROL & THERMAL EFFECTS
- SMALL PERFORMANCE GAINS BETWEEN OPTIONS ARE EXPENSIVE

RC25/RO25: MATCHING SOUNDER CENTROIDS & HALF POWER IGFOVS

- DIFFRACTION LIMITS DEGREE OF SIMILARITY OF SPATIAL WEIGHTING FUNCTION SHAPES
- FABRICATION & CALIBRATION TECHNIQUES LIMIT ACCURACY OF MATCHING CENTROIDS
- THERMAL & LIFETIME STABILITY OF BEAM SPLITTER OPTICS LIMITS STABILITY OF CO-REGISTRATION ACROSS 3 BANDS

IMPACTS TO SPACECRAFT JUDGED EXCESSIVE

RO1: INCREASE RESOLUTION/ADD SPECTRAL BAND

- LARGER APERTURE TO MINIMIZE DIFFRACTION IN 10 μm BAND MUCH LARGER APERTURE TO MEET NEΔT IN 13 μm BAND

RC4: CHANNEL-CHANNEL REGISTRATION

- CALIBRATION/ALIGNMENT/FABRICATION LIMITATIONS
- THERMAL EFFECTS
- BEAM SPLITTER STABILITY
- INSTABILITIES ASSOCIATED WITH VIEWING CHANNELS AT DIFFERENT TIMES

RC7/RO7: SENSITIVITY (NEΔT)

- COLDER FOCAL PLANE REQUIRES MECHANICAL REFRIGERATION
- BETTER DETECTORS
- LARGER APERTURE

RC8: CLOUD SMEAR

- REWORD REQUIREMENT TO MAKE SPEC INDEPENDENT OF IFOV
- REQUIRES LARGER APERTURE FOR LONGWAVE CHANNELS

RE13: VISIBLE CHANNEL CALIBRATION – POSSIBLE AT TIMES OF OPPORTUNITY

- VIEW SUN THROUGH ATTENUATOR
- USE MOON

RE14: LOW LIGHT IMAGER

- MODIFY LIGHTNING MAPPER RATHER THAN IMAGER; NON DEDICATED OPERATION
- MODIFIED LIGHTNING MAPPER PROVIDES 10KM IFOV
- PERFORMANCE COULD BE IMPROVED IN ADVANCED LIGHTNING MAPPER

RE21: SOUNDER SPATIAL RESOLUTION OF 4KM (MAJOR IMPACT TO LONGWAVE CHANNELS)

- MUCH LARGER APERTURE TO MINIMIZE DIFFRACTION AND MEET NEΔT

RO18: NIGHT TIME 4μm CLOUD DETECTION AT 2KM

- REFRIGERATION FOR 80 IR DETECTORS

RO20: SINGLE PIXEL SOUNDING

- INADEQUATE S/N FOR REQUIRED TEMPORAL & SPATIAL RESOLUTIONS AT SOUNDING RATES

RO22: SOUNDING RATE 3000 X 3000KM IN 30 MINUTES; 2500 X 2500KM IN 20 MINUTES

- COLDER FOCAL PLANE REQUIRES MECHANICAL REFRIGERATION
- BETTER DETECTORS
- LARGER APERTURE

RO33: SOLAR EUV SPECTROMETER

- MAJOR YOKE REDESIGN TO ACCOMMODATE ALL SOLAR VIEWING INSTRUMENTS

RC31: SEM/EPS

- <0.8MeV/n ALPHA PARTICLE MEASUREMENTS – COMPLETELY NEW SENSOR
- PITCH ANGLE DISTRIBUTIONS FOR PROTONS AND ELECTRONS ABOVE 30keV – TOTAL REDESIGN REQUIRED

RC35: S&R LOCATION CAPABILITY

- INTERFEROMETER BOOMS IMPACT OPTIONS I, II, & II CONTROL SYSTEM & AFFECT COOLER OPERATION

RC36: DCS ADDITIONAL CHANNELS & LOCATION CAPABILITY

- IMPACTS OPTION I POWER & WEIGHT
- LOCATION OF UNFRIENDLY TRANSMITTER NOT FEASIBLE

RC37: WEFAX ADDITIONAL CHANNELS & OPERATION DURING ECLIPSE

- IMPACTS OPTION I POWER & WEIGHT

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